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Flexible Thermal Protection Materials for Entry Systems

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Background

- Composite Flexible Blanket Insulation (CFBI)
    - Silicon Carbide Interlock top fabric
    - Contains reflector shields-- aluminized Kapton
    - Alumina Insulation
    - IML has 2 inch centers to reduce foil/fabric damage
    - Thermally stable (short term) at heat flux rates up to 31 Btu/ft^2•s, surface temperatures ~2700°F
    - Density similar to AFRSI-TABI
    - Lower thermal conductivity at high temperatures than AFRSI or TABI
    - Requires ceramic coating for exposure to higher heating rates
    - Vibroacoustic performance of ceramic coating unknown

Background

- Types of Flexible TPS currently available
    - Tailorable Advanced Blanket Insulation (TABI)
        - Integrally woven with silicon carbide yarn
        - Insulation is alumina or aluminoborosilicate
        - Thermally stable (short term) at heat flux rates up to 31 Btu/ft^2•s, surface temperatures ~2700°F
        - Thermal Conductivity approximately similar to AFRSI
        - Better vibroacoustic performance (Interlock version) than AFRSI
        - Density 9-10 lb/ft^2, approximately similar to AFRSI
        - Requires ceramic coating for exposure to higher heating rates

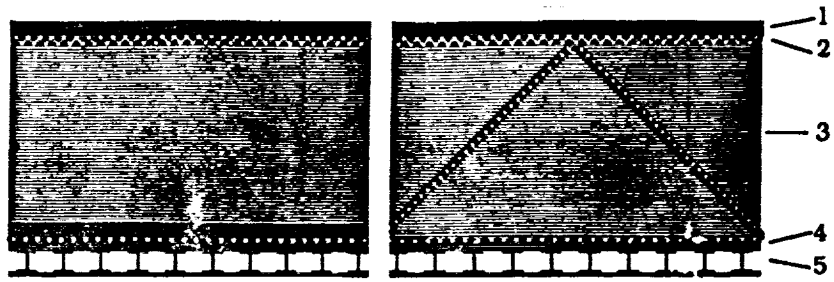
Technology Needs

- High temperature (>1800 °F) ***Flexible Coating*** for flexible insulations/fabrics
- Flexibility required for TPS installation purposes
- Present coating applied "green" or unfired and rely on entry heat for curing.
- Suitable for fast reentry such as AFE, may not be suitable for slower reentries.
- Prior firing may be required to survive
  - High (>165 dB) vibroacoustic loads
  - High aerodynamic effects
  - Particulate impact and
  - Moisture effects
- Should not provide significant weight penalty (>15%)
- Have suitable emissivity values ≥ 0.85

Technology Needs

- Simple, Lightweight, Durable and Waterproof Insulations
  - Intermediate (~ 2000 °F) temperature applications.
  - Utilize existing AFRSI, TABI or CFBI fabrication technology Use 2 inch centers on AFRSI or CFBI.
  - Utilize metal coated ceramic (Nextel, etc.) OML fabric.
  - Use existing graphite coating technology.
  - Bond metal foil (Ni, etc.) on OML fabric utilizing induction brazing techniques.
  - Provides non-stitched impermeable surface
  - Resistant to moisture/water, high vibroacoustic loads, and aerodynamic effects

Metallic CFBI / TABI



1 Metal Surface (Induction Brazed to Fabric)

2 Ceramic Fabric with Embedded Woven Wires or Metal coated Fabric

3 Ceramic Insulation with Reflective Metal foils (left) or Ceramic Fabric Supports (right)

4 Bond (RTV)

5 Vehicle Structure

Technology Gaps for Flexible Insulations

- Ceramic Coatings
  - Require high temperature firing-- reduce mechanical properties of fibers/fabrics
  - Weight penalty
  - Reduce flexibility
  - Questionable reusability
  - Low adhesion (unfired)
- Metallic Surfaces
  - Temperature limitation due to oxidation
- Close-out of complex shapes
- Instrumentation, installation and attachment methods

Highest Payoff Areas for Flexible Insulations

- Low cost fibers for high-temperature applications
- Simplify fabrication procedures for insulations
- Effective coatings-- use with low cost fibers

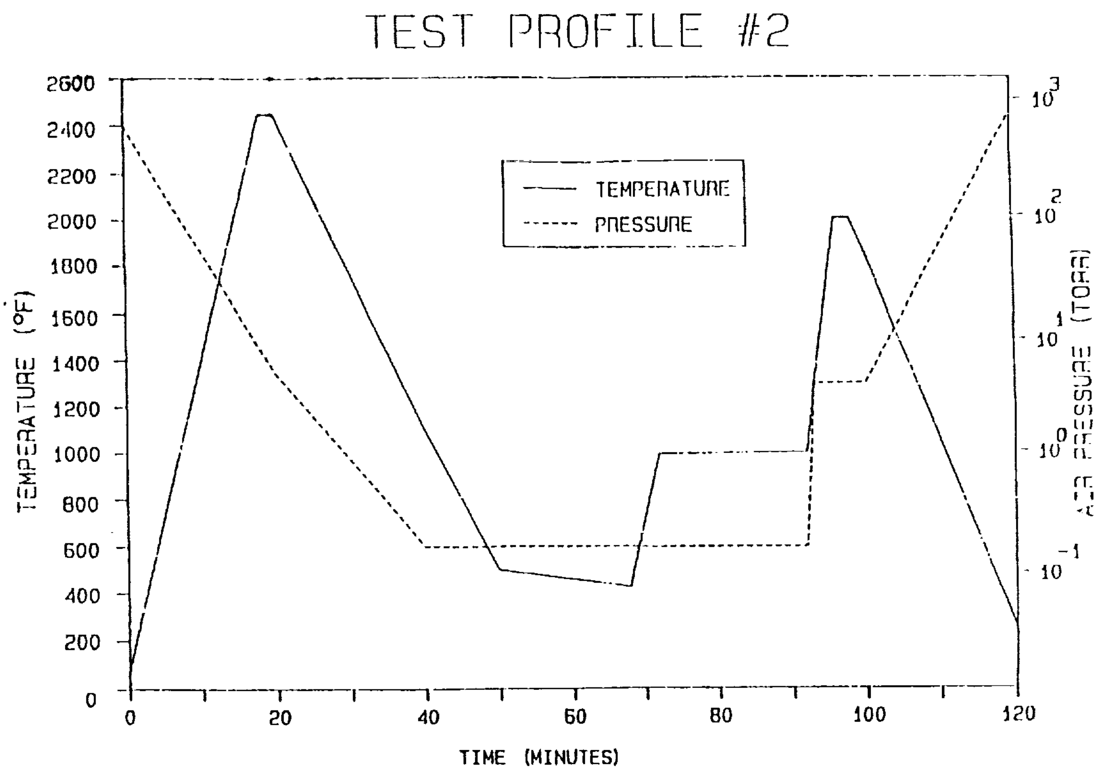
CURRENT HEAT SHIELD MATERIALS THERMAL LIMITS

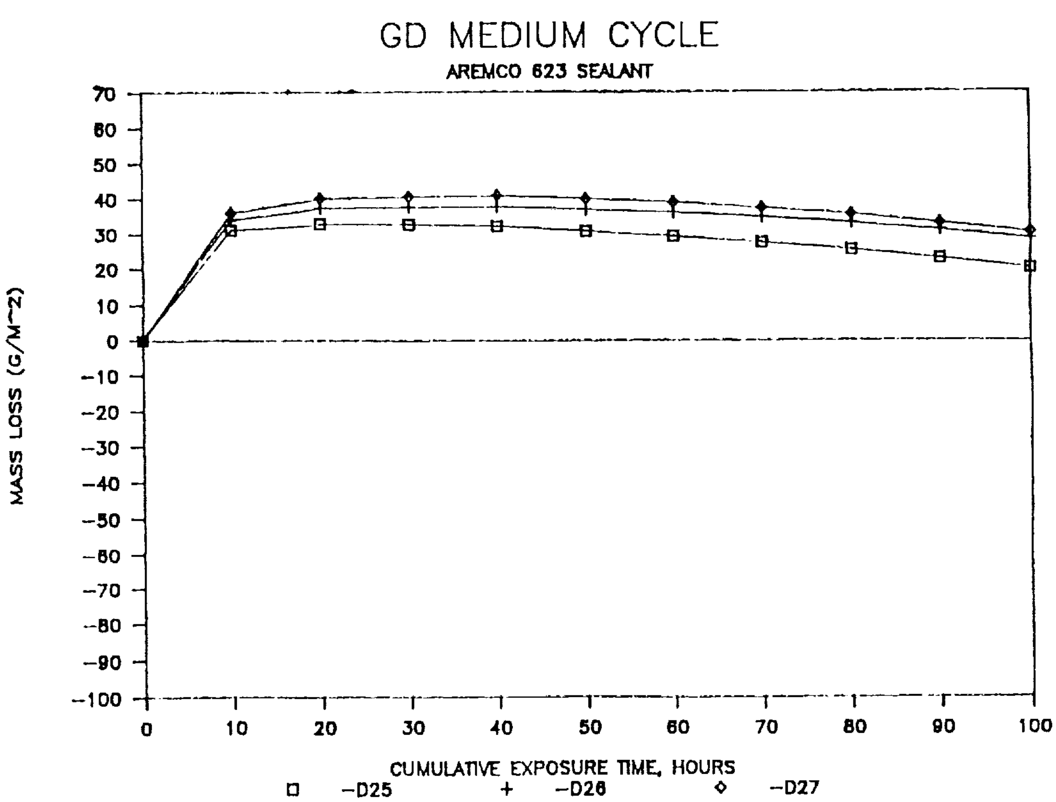
MATERIAL	MAXIMUM USE TEMPERATURE, °F MULTIPLE FLIGHT	MAXIMUM USE TEMPERATURE, °F SINGLE FLIGHT	EMITTANCE (@ °F)	MAXIMUM HEAT FLUX CAPABILITY* BTU/FT²-SEC	EQUIVALENT USE TEMPERATURE, °F*
FLEXIBLE ORGANIC					
FRSI	700	800	.9(800)	1.4	865
PBI	900+	1100	.9(1100)	2.7	1125
AFRSI, TABI, CFBI					
SILICA	1200	2000	.43(2000)	4.4	1480
NEXTEL	> 2000	> 2000	.48(2000)	> 7.5	1620
NICALON	2000	> 2400	.58(2000)	> 30	
RIGID CERAMIC INSULATION					
LI-900	2500	2700	.9(2500)	60	2960
LI-2200	2600	2800 (2900 FOR AFE)		(80)	
FRCI-12	2600	2800	.9(2500)	70	3115
AETB-12/TUFI	2500	2700**		60	
AETB-12/RCG	2600+**	2800+**		70	
ASMI	2600+**	2900**		80	
AETB-8/RCG	2600**	2800+**		70	
METAL			.8		
TITANIUM	1000			1.7	1000
RENE 41	1600			6.9	1600
INCONEL 617	2000			14	2000
RCC/ACC	3000		.8	55 (F.C.) 100 N.C.	3000 3560

Current Programs

- Aeroassist Flight Experiment
  - Evaluate thermal performance of advanced Rigid and Flexible Insulations and Reflective Coating
  - Lighter than baseline materials
  - Rigid insulations perform well
  - Flexible insulations require ceramic coating
  - Reflective Coating effective at >15% radiative
- NASP
  - High and low temperature insulations
  - Attachment/standoff methodology critical-- affects thermal performance

10.3.7 Recent Advanced Carbon-Carbon Efforts at LTV
by Garland B.Whisenhut, LTV Missiles and Electronics Group


TEST PROFILE #2
TEMPERATURE
PRESSURE
TEMPERATURE (°F)
AIR PRESSURE (TORR)
TIME (MINUTES)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
20
40
60
80
100
120
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}


GD MEDIUM CYCLE
AREMCO 623 SEALANT
MASS LOSS (G/M^2)
CUMULATIVE EXPOSURE TIME, HOURS
□ -D25
+ -D26
◇ -D27
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
10
20
30
40
50
60
70
80
90
100

CONCLUSIONS

- ACC SUBSTRATE FABRICATION TECHNOLOGY IN GOOD SHAPE.
- ACC COATING IMPROVEMENTS SATISFACTORY BUT ADDITIONAL WORK NEEDED.
- NON-DESTRUCTIVE TEST TECHNIQUES TO MONITOR HARDWARE DURING OPERATIONAL LIFE NEEDED.
- COST REDUCTION APPROACHES A HIGH PRIORITY.